

## What is Claimed:

1                   1.       A bias fiber holder for holding a bias fiber under tension, as part  
2 of a loom, comprising;

3                   a ceramic vacuum cylinder to hold a bias fiber under tension; and

4                   gripping means adapted to be releasably gripped by at least one of a  
5 bias shuttle and an independently controllable bias arms.

1                   2.       The bias fiber holder according to claim 1, wherein a vacuum is  
2 applied to the ceramic vacuum cylinder by the bias shuttle, when the bias fiber  
3 holder is being gripped by the bias shuttle.

1                   3.       The bias fiber holder according to claim 1, wherein the gripping  
2 means is a plurality of tubes.

1                   4.       The bias fiber holder according to claim 3, wherein the plurality  
2 of tubes include:

3                   a pair of shuttle gripping tubes configured to be releasably gripped by  
4 the bias shuttle; and

5                   a pair of arm gripping tubes configured to be releasably gripped by the  
6 independently controllable bias arm.

1                   5.     A loom for weaving three dimensional structures which include  
2     a plurality of warp fibers, a fill fiber, and a plurality of bias fibers, the loom  
3     comprising:

4                   a plurality of bias fiber holders, each bias fiber holder holding a bias  
5     fiber under tension;

6                   a plurality of bias shuttles, each bias shuttle releasably gripping at  
7     least one of the plurality of bias fiber holders and translating horizontally, at a  
8     separate vertical position, the gripped bias fiber holders between a plurality of  
9     predetermined horizontal positions, at least one bias shuttle configured to translate  
10    above a shed formed by the warp fibers and at least one bias shuttle configured to  
11    translate below the shed; and

12                  a plurality of independently controllable bias arms, each independently  
13    controllable bias arm releasably gripping one of the plurality of bias fiber holders and  
14    translating the gripped bias fiber holder, at one of the predetermined horizontal  
15    positions, with a range of motion extending at least between two of the bias shuttles.

1                   6.     A loom for weaving three dimensional structures which include  
2     a plurality of warp fibers, a fill fiber, and a plurality of bias fibers, the loom  
3     comprising:

4                   a plurality of heddles, each heddle engaging one of the plurality of  
5     warp fibers and independently translating the engaged warp fiber vertically between  
6     at least one upper warp position and at least one lower warp position, forming a  
7     shed;

8                   a plurality of bias fiber holders, each bias fiber holder holding a bias  
9   fiber under tension;

10                  a plurality of bias shuttles, each bias shuttle releasably gripping at  
11   least one of the plurality of bias fiber holders and translating horizontally, at a  
12   separate vertical position, the gripped bias fiber holders between a plurality of  
13   predetermined horizontal positions, at least one bias shuttle configured to translate  
14   above the shed and at least one bias shuttle configured to translate below the shed;

15                  a plurality of independently controllable bias arms, each independently  
16   controllable bias arm releasably gripping one of the plurality of bias fiber holders and  
17   translating the gripped bias fiber holder, at one of the predetermined horizontal  
18   positions, with a range of motion extending at least between two of the bias shuttles;

19                  a weave shuttle passing the fill fiber through the shed formed by the  
20   warp fibers and the bias fibers substantially along a centerline of the shed; and

21                  a reed for beat up.

1                   7.       The loom according to claim 6, wherein the plurality of heddles  
2   are Jacquard-controlled.

1                   8.       The loom according to claim 6, wherein the plurality of bias  
2   shuttles further includes at least one bias shuttle configured to translate within the  
3   shed.

1                   9.     The loom according to claim 6, wherein each bias fiber holder  
2 includes a ceramic vacuum cylinder to hold a bias fiber under tension.

1                   10.    The loom according to claim 9, wherein each bias shuttle  
2 applies a vacuum to the ceramic vacuum cylinder of each bias fiber holder being  
3 translated by the bias shuttle.

1                   11.    The loom according to claim 6, wherein each bias fiber holder  
2 includes a plurality of tubes configured to be releasably gripped by at least one of the  
3 plurality of bias shuttles and the plurality of independently controllable bias arms.

1                   12.    The loom according to claim 11, wherein the plurality of tubes  
2 of each bias fiber holder include:

3                   a pair of shuttle gripping tubes configured to be releasably gripped by  
4 the plurality of bias shuttles; and

5                   a pair of arm gripping tubes configured to be releasably gripped by the  
6 plurality of independently controllable bias arms.

1                   13.    The loom according to claim 6, wherein the plurality of  
2 predetermined horizontal positions are selected such that each of the plurality of  
3 warp fibers is between two of the predetermined horizontal positions.

1                   14.    The loom according to claim 6, wherein the plurality of  
2 independently controllable bias arms includes:

3                   an upper subset of independently controllable bias arms, the range of  
4   motion of each independently controllable bias arm of the upper subset extending  
5   from above the shed to the centerline of the shed; and

6                   a lower subset of independently controllable bias arms, the range of  
7   motion of each independently controllable bias arm of the lower subset extending  
8   from below the shed to the centerline of the shed.

1                   15.    The loom according to claim 14, wherein:

2                   a subset of the predetermined horizontal positions is selected to be  
3   located between pairs of warp fibers; and

4                   the independently controllable bias arms are configured such that one  
5   of the upper subset and one of the lower subset of the independently controllable  
6   bias arms in each of the subsets of the predetermined horizontal positions align to  
7   transfer a gripped bias fiber holder between the two aligned independently  
8   controllable bias arms at the centerline of the shed in one of the subsets of the  
9   predetermined horizontal positions.

1                   16.    A loom for weaving three dimensional structures which include  
2   a plurality of warp fibers, a fill fiber, and a plurality of bias fibers, the loom  
3   comprising:

4                   a plurality of heddles, each heddle engaging one of the plurality of  
5   warp fibers and independently translating the engaged warp fiber vertically between

6 at least one upper warp position and at least one lower warp position, forming a  
7 shed;

8 a plurality of bias fiber holders, each bias fiber holder including a  
9 ceramic vacuum cylinder configured to hold a bias fiber under tension;

10 a plurality of bias shuttles, each bias shuttle releasably gripping at  
11 least one of the plurality of bias fiber holders and translating horizontally, at a  
12 separate vertical position, the gripped bias fiber holders between a plurality of  
13 predetermined horizontal positions, at least one bias shuttle configured to translate  
14 above the shed, at least one bias shuttle configured to translate below the shed, and  
15 at least one bias shuttle configured to translate within the shed;

16 wherein the plurality of predetermined horizontal positions are selected  
17 such that each of the plurality of warp fibers is between two of the predetermined  
18 horizontal positions;

19 a plurality of independently controllable bias arms, each independently  
20 controllable bias arm releasably gripping one of the plurality of bias fiber holders and  
21 translating the gripped bias fiber holder, at one of the predetermined horizontal  
22 positions, the plurality of independently controllable bias arms including;

23 an upper subset of independently controllable bias arms, the range of  
24 motion of each independently controllable bias arm of the upper subset extending  
25 from above the shed to the centerline of the shed; and

26                   a lower subset of independently controllable bias arms, the range of  
27   motion of each independently controllable bias arm of the lower subset extending  
28   from below the shed to the centerline of the shed with a range of motion extending  
29   at least between two of the bias shuttles;

30                   wherein each bias fiber holder includes a plurality of tubes configured  
31   to be releasably gripped by at least one of the plurality of bias shuttles and the  
32   plurality of independently controllable bias arms;

33                   a weave shuttle passing the fill fiber through the shed formed by the  
34   warp fibers and the bias fibers substantially along a centerline of the shed; and

35                   a reed for beat up.

1                   17.    The loom according to claim 16, wherein the plurality of  
2   heddles are Jacquard-controlled.

1                   18.    The loom according to claim 17, wherein each bias shuttle  
2   applies a vacuum to the ceramic vacuum cylinder of each bias fiber holder being  
3   translated by the bias shuttle.

1                   19.    The loom according to claim 17, wherein the plurality of tubes  
2   of each bias fiber holder include:

3                   a pair of shuttle gripping tubes configured to be releasably gripped by  
4   the plurality of bias shuttles; and

5                   a pair of arm gripping tubes configured to be releasably gripped by the  
6   plurality of independently controllable bias arms.

1                   20.    The loom according to claim 17, wherein:

2                   a subset of the predetermined horizontal positions is selected to be  
3   located between pairs of warp fibers; and

4                   the independently controllable bias arms are configured such that one  
5   of the upper subset and one of the lower subset of the independently controllable  
6   bias arms in each of the subsets of the predetermined horizontal positions align to  
7   transfer a gripped bias fiber holder between the two aligned independently  
8   controllable bias arms at the centerline of the shed in one of the subsets of the  
9   predetermined horizontal positions.